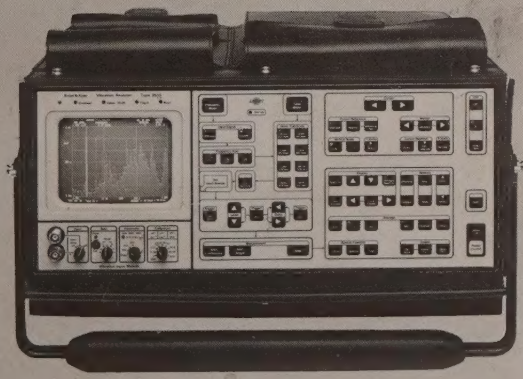
Field Guide

Vibration Analyzer Type 2515



Brüel & Kjær

Field Guide
Vibration Analyzer
Type 2515

From serial no. 1204088

May 1986

SAFETY CONSIDERATIONS

This apparatus has been designed and tested according to IEC Publication 348, *Safety Requirements for Electronic Measuring Apparatus*, and has been supplied in safe condition. The present Instruction Manual contains information and warnings which should be followed by the user to ensure safe operation and to retain the apparatus in safe condition. Special note should be made of the following:

APPLICATION OF POWER

Before each use of the Power Supply ZG 0249 with the apparatus, check that it is set to match the available mains voltage and that the correct fuse is installed.

SAFETY SYMBOLS

⚠ The apparatus will be marked with this symbol when it is important that the user refers to the associated warning statements given in the Instruction Manual.

⊥ Chassis terminal ⏚ Safety earth terminal ⚡ Hazardous voltage.

WARNINGS

Switch off all equipment before connecting or disconnecting their digital interface. Failure to do so could damage the equipment.

Whenever it likely that the correct function or operating safety of the apparatus has been impaired, the apparatus must be made inoperative and be secured against unintended operation.

Any adjustment, maintenance and repair of the open apparatus under voltage must be avoided as far as possible and, if unavoidable, must be carried out only by trained service personnel.

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1. General

Within the text, a pushbutton group is identified by being written in bold, while a particular pushbutton within a group is written in bold and enclosed in quotation marks (i.e. **Average "Start"**). As part of the descriptions on the use of the 2515, the pushbuttons or controls to be used are indicated with a red circle on a Front Panel drawing. Those controls marked with an empty circle are set before taking the measurement (i.e. ○). The controls marked with a numbered circle are used in the numbered order and as described in the text (i.e. ①).

1. General

Power Supply:

The 2515 is powered by an internal battery pack or by the Power Supply ZG 0249. The ZG 0249 simultaneously charges the battery pack. The memory is powered by a separate internal battery which is recharged from the battery pack while the 2515 is in use. Memory duration is typically 1 month with the 2515 in storage at 25°C.

A 10 A slow blow fuse (B & K part number VF 0024) is fitted to the battery pack.

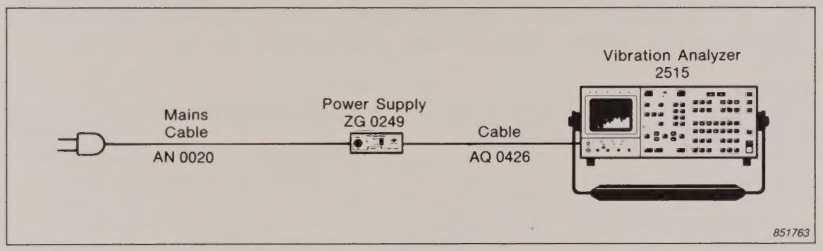
Use of the Battery Pack:

Switch to **Power "Internal"** on the 2515 Rear Panel. Battery life is typically 4 hours with **CRT "On"**.

The battery life can be increased using the **CRT** controls. **CRT "Off"** switches the display screen off while all other functions remain active. **CRT "Power Save"** switches the display screen off after approximately 15 seconds if no Front Panel control is used. The screen automatically re-activates when a Front Panel control is used.

To keep the battery pack in good condition, the batteries should be alternately charged and discharged rather than maintaining the batteries at a full charge. Therefore whenever it is practical, the 2515 should be used on internal power and recharged only when the batteries are low.

Use of the Power Supply ZG 0249:



⚠ **Warning:** The mains voltage setting and fuse rating of the ZG 0249 should be checked before connecting the mains supply.

200 to 240 V AC — 0,5 A slow blow fuse (B & K part number VF 0023)
100 to 127 V AC — 1,0 A slow blow fuse (B & K part number VF 0013)

Switch to **Power "External"** on the 2515 Rear Panel and switch the ZG 0249 to **"140 mA"** or **"600 mA"**.

"600 mA" typically to recharge the battery pack after use.
"140 mA" typically to maintain the battery pack charge.

The ZG 0249 will recharge the battery pack with the 2515 switched on or off. The LED indicator marked **"Charging"** on the ZG 0249 is lit to show that the ZG 0249 is correctly connected (and remains lit when charging is complete). The LED indicator **"Low Battery Voltage"** is lit if the battery pack is discharged or if a cell is short circuited. 18 hours at **"600 mA"** will recharge a fully discharged battery pack.

⚠ **Warning:** The ZG 0249 should be used to charge/drive a single 2515 with cable AQ 0426 or to charge a separate battery pack with cable AQ 0439.

Screen Intensity:

The display screen brightness is adjusted by turning the **CRT Intensity Control** on the Rear Panel. The brightness is controlled with respect to ambient light by pushing in the **CRT Intensity Control**.

The reflex filter (supplied) is used to reduce glare from the display screen.

2. The Vibration Input Module

Input:

Set the **Input** knob to **"V"**, **"pC"** or **"μA"** to suit a voltage, charge or line-drive input device. The following table can be used as a guide.

Input Device	Accelerometer			Proximity Probe	Tape Recorder	AC Output from Permanent Monitor
	4371, 4384 & 4391	4390	+ 2644			
Input Setting	"pC"	"μA"	"μA"	"V"	"V"	"V"

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Parameter:

Choose the **Parameter** giving the flattest spectrum in the frequency range of interest. The following table can be used as a guide.

Machine	Parameter Setting	
	Accelerometer	Proximity Probe
Rolling element bearings	"Acc"	Not recommended
Journal bearings	"Vel"	"Disp"
Electric motor, gearbox, compressor or gas turbine	"Vel"	Not recommended
Reciprocating machine	"Acc"	Not recommended
Hydro turbine	"Vel" or "Disp"	"Disp"

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Ensure that the **Low freq. limit** is less than 1/3 of the minimum rotational speed when measuring the vibration from a journal bearing (a bearing with no rolling elements) and is less than the minimum rotational speed when measuring the signal from a rolling element bearing.

The **Low freq. limit** is changed using a switch inside the Input Module. Refer to the 2515 Instruction Manual before adjustment.

Calibration:

Set the **Calibration** knob to the sensitivity of the input device.

Input Device	Accelerometer			Proximity Probe	Tape Recorder	AC Output from Permanent Monitor
	4371, 4384 & 4391	4390	+ 2644			
Input Setting	" ① "	" ① "	Sensitivity of accelerometer	"200"	Sensitivity of input device	Sensitivity of input device

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The **Cal.** control is used to calibrate the 2515 with non-unity gain input devices (those with sensitivities other than the **Calibration** control settings). See the 2515 Instruction Manual.

Gain:

Adjust the **Gain** until the **"Upper 10 dB"** indicator is on (or flashes on) and the **"Overload"** indicator remains off. In the case of a weak signal when the **"Upper 10 dB"** indicator does not light, use the maximum **Gain** or a more sensitive accelerometer.

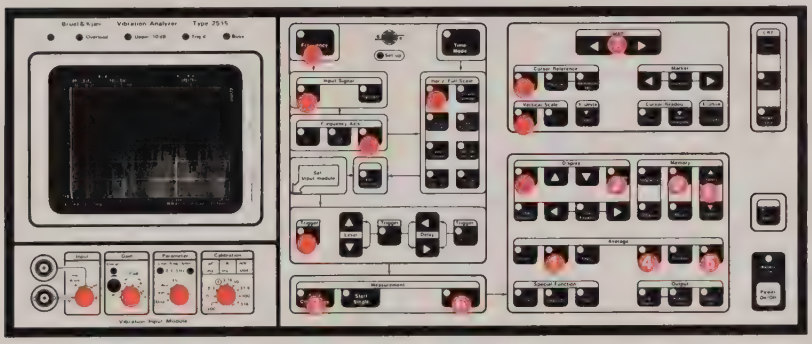
Ensure that the LED indicator **"Uncal."** is off when using a unity gain input device.

3. Fault Detection

Machine faults are detected by monitoring the vibration of the machine during operation. Each newly measured spectrum is compared with an earlier spectrum (the reference spectrum) measured at the same point on the machine. The period between measurements, the location of the measurement points and the measured frequency ranges are decided by the machine type, operating conditions and the likely modes of failure. For example, measurements are often taken every two months on bearing housings. Significant changes in the spectrum indicate a possible machine fault. A change of a factor 2,5× (8 dB) is considered to be significant for most machines and 10× (20 dB) is considered to be the maintenance limit. The diagnosis of the fault is discussed in section 4.

3.1. Storing a Reference Spectrum

Frequency Axis "Log. 6 %" is recommended when comparing spectra to detect faults in machinery. For most machines **Horiz. Full-Scale "10 kHz"** or **"20 kHz"** should be used. To measure and store a reference spectrum with **Horiz. Full-Scale "20 kHz"**:



○ Set the controls and pushbuttons marked with a blank circle.

① Press **Average "Lin."**.

② Press **Display "Averaged Spectrum"**.

③ Press **Measurement "Start Continuous"**.

④ Press **Average "Start"**.

⑤ When the averaged spectrum no longer changes, press **Average "Stop"**.

⑥ Press **Measurement "Stop"**.

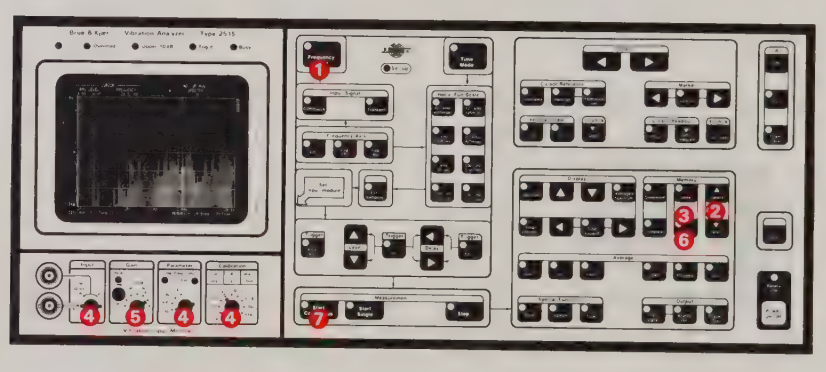
⑦ Move the cursor to the rotational speed using **Cursor "◀ ▶"**.

⑧ Press **Memory "Select ▲"** or **"Select ▼"** to select a suitable memory location (not memory location 0).

⑨ Press **Memory "Store"** (twice if the memory location is **"Used"**).

3.2. Measuring a New Spectrum

To repeat the measurement taken in section 3.1 using new data:



① Press **"Frequency Mode"** (even if the **"Frequency Mode"** LED is already lit).

② Press **Memory "Select ▲"** or **"Select ▼"** to select the memory location of the reference spectrum.

③ Press **Memory "Recall"**.

④ Set the **Vibration Input Module** to the settings shown on the display screen. The recalled settings are not shown if the **Vibration Input Module** settings are correct.

⑤ Set the **Gain** to suit the new input signal.

⑥ Press **Memory "Recall"** again if it was necessary to alter the **Vibration Input Module**.

⑦ Press **Measurement "Start Continuous"**. Averaging will stop when the number of averages is equal to the number of averages used for the reference spectrum.

3.3. Comparison and Storage

The measured spectrum can be compared to the reference spectrum using **Memory "Difference"** or **Memory "Compare"**. **"Compare"** alternates the current display with the display stored in the indicated memory location. **"Difference"** displays the difference between the current display and the display stored in the indicated memory location. This is the recommended method of comparison. The difference spectrum is speed compensated by an automatic realignment of the 2 cursor frequencies when using **Frequency Axis "Log. 6 %"**. Comparisons with a speed variation greater than 12 % are accompanied by an advisory screen message and should be avoided.

The measured spectrum can be stored using **Memory "Store"**.

To display the difference between the new measurement (section 3.2) and the reference spectrum (section 3.1):

1. Adjust the cursor to the rotational speed using **Cursor "◀ ▶"**.
2. Press **Memory "Select ▲"** or **"Select ▼"** to select the memory location of the reference spectrum.
3. Press **Memory "Difference"**. A spectrum difference with speed compensation is shown.

To store the new measurement:

1. Press **Memory "Difference"** or **Memory "Compare"**, if they are active. This will return the measurement display.
2. Adjust the cursor to the rotational speed using **Cursor "◀ ▶"**.
3. Press **Memory "Select ▲"** or **"Select ▼"** to select a new memory location number.
4. Press **Memory "Store"** (twice if the memory location is **"Used"**).

4. Fault Diagnosis

The usual method of diagnosing faults in rotating machinery is:

1. To determine the rotational speed of the machine using a low frequency spectrum. The rotational speed can be determined more precisely by zooming about the rotational speed.
2. To identify the components of a high frequency spectrum and relate these to the frequencies of the various machine elements and the likely faults. See the troubleshooting chart on the back cover.

The following table is a guide to the frequency ranges and the techniques used to identify some common faults in rotating machinery.

Fault	Horiz. Full-Scale	Special Techniques
Unbalance	$4 \times F_{Rot}$	Compare the amplitudes of the harmonics – See balancing section 5
Misalignment – Bent shaft	$8 \times F_{Rot}$	Harmonic marker – Phase measurement
Loose fit	$10 \times F_{Rot}$	Harmonic marker
Oil whirl	$2 \times F_{Rot}$	Zoom
Hysteresis whirl	$2 \times F_{Rot}$	Tracking – Scan averaging
Belt drive fault	10 × Belt Speed	Harmonic marker – Cepstrum analysis
Electrical vibration asynchronous machine	200 Hz	Zoom at 2 × mains frequency – Time averaging
Electrical vibration synchronous machine	200 Hz	Coast down test – Scan averaging
Ball bearing fault	$10 \times N_B \times F_{Rot}/2$	Harmonic marker – Cepstrum analysis
Uniform wear in gears	$3 \times N_T \times F_{Rot}$	Harmonic marker
Cracked teeth in gears	$> N_T \times F_{Rot}$	Harmonic cursor – Zoom around $N_T \times F_{Rot}$ – Cepstrum
Resonance check by hammer impact	See section 4.9	Internal trigger
Run up & coast down – Critical speed check	Highest harmonic of interest	Track (slow run up / down) – Scan (fast run up / down)

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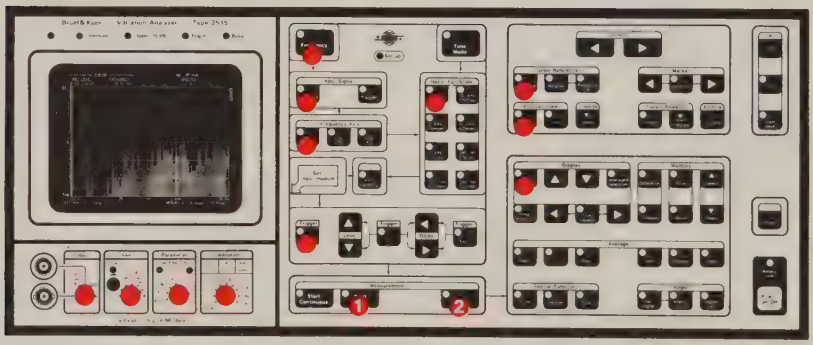
F_{Rot} = rotational speed (Hz) N_B = number of balls/rollers N_T = number of teeth

4.1. Spectrum Analysis

The baseband constant bandwidth spectrum (an unzoomed spectrum with **Frequency Axis "Lin."** selected) is the most widely used diagnostic technique and forms the basis of any further analysis. Spectrum analysis is usually applied to continuous signals using a logarithmic vertical scale. The **Horiz. Full-Scale** is selected to suit the measurement. See the table on the previous page.

For example, to measure a constant bandwidth spectrum with **Horiz. Full-Scale "20 kHz"**:

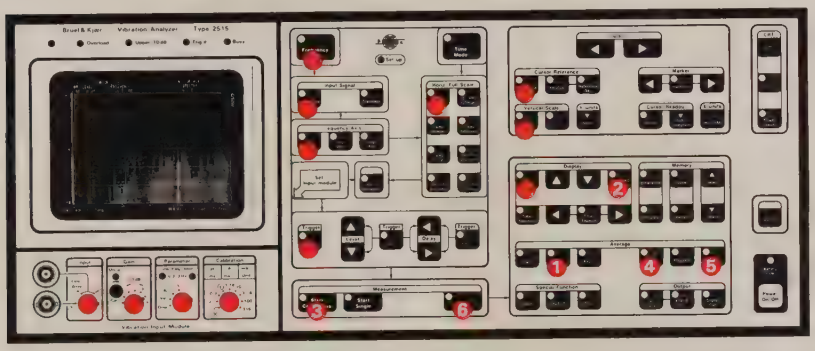


○ Set the controls and pushbuttons marked with a blank circle.

① Press **Measurement "Start Single"**.

② Wait until **Measurement "Stop"** is lit.

Spectra can also be averaged. For example, to measure a linear averaged spectrum with **Horiz. Full-Scale "20 kHz"**:



○ Set the controls and pushbuttons marked with a blank circle.

① Press **Average "Lin."**.

② Press **Display "Averaged Spectrum"**.

③ Press **Measurement "Start Continuous"**.

④ Press **Average "Start"**.

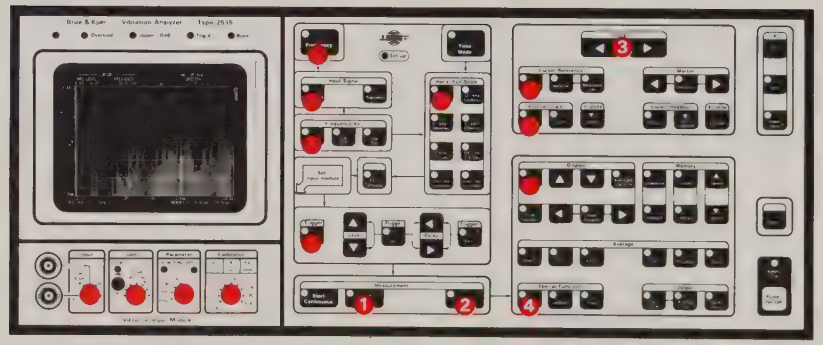
⑤ Press **Average "Stop"** when the averaged spectrum no longer changes.

⑥ Press **Measurement "Stop"**.

4.2. Zoomed Spectrum Analysis

The zoom improves the frequency resolution by a factor of 5. A zoomed spectrum can be used to accurately measure the frequency of a component and to separate closely spaced frequency components. This is useful, for example, when separating electromagnetically induced vibration (typically from the mains) from the vibration caused by mechanical components.

To make a zoom measurement with **Horiz. Full-Scale "20 kHz"**:



○ Set the controls and pushbuttons marked with a blank circle.

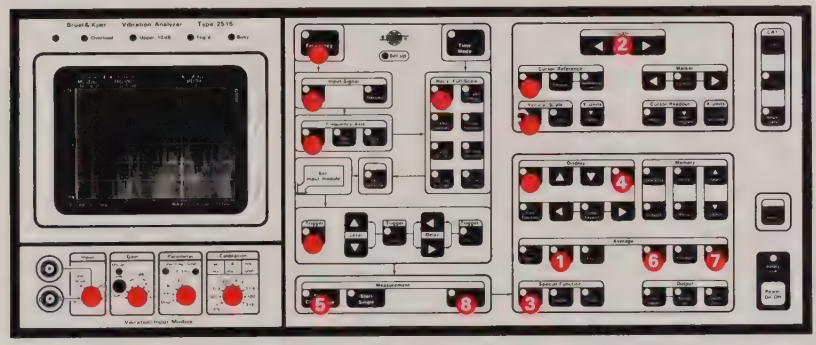
① Press **Measurement "Start Single"**.

② Wait until **Measurement "Stop"** is lit.

③ Move the cursor to the frequency to be zoomed using **Cursor "◀ ▶"**.

④ Press **Special Function "Zoom"**. The zoomed spectrum will appear after approximately 10 seconds.

Zoomed spectra can also be averaged. To measure a linear averaged zoom with **Horiz. Full-Scale "20 kHz"**:



○ Set the controls and pushbuttons marked with a blank circle.

① Press **Average "Lin."**.

② Move the cursor to the frequency to be zoomed using **Cursor "◀ ▶"**.

③ Press **Special Function "Zoom"**.

④ Press **Display "Averaged Spectrum"**.

⑤ Press **Measurement "Start Continuous"**.

⑥ Press **Average "Start"**.

⑦ Press **Average "Stop"** when the averaged spectrum no longer changes.

⑧ Press **Measurement "Stop"**.

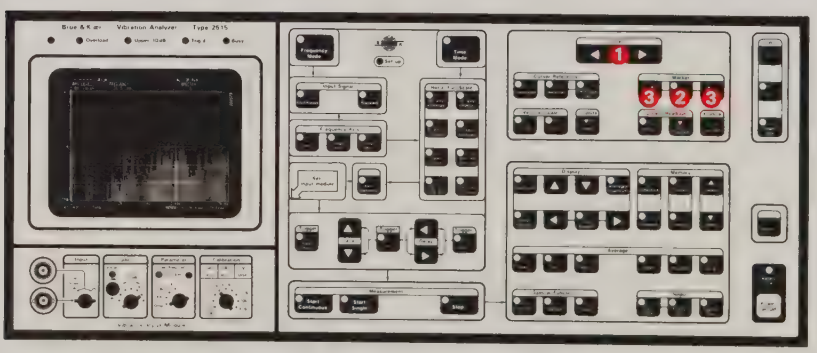
4.3. Harmonic Marker

The harmonic marker is used to identify families of harmonics. The main uses of the harmonic marker are:

1. To study the harmonics of a rotational speed. These can indicate looseness, rubbing, cracked gear teeth, gear eccentricity, blade faults, etc.
2. To study the harmonics of the impact rates of bearing rolling elements. These can indicate a local fault in a bearing.
3. To study the harmonics of a belt rotation speed. These can indicate a fault in the belt drive.

The harmonic marker can be fine tuned to accurately measure the fundamental frequency. Fine tuning is not possible with **"Log. 23 %"** or **"Log. 6 %"** spectra.

To use the harmonic marker, measure a single or averaged spectrum with **Frequency Axis "Lin."** and then:

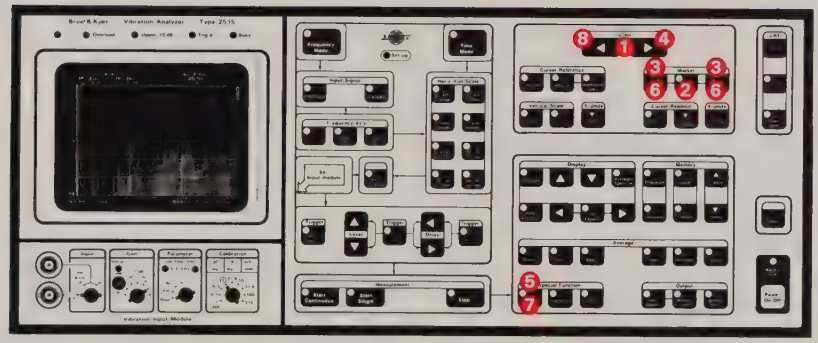


① Move the cursor to the fundamental frequency using **Cursor "◀ ▶"**.

② Press **Marker "Harmonic"**.

③ Adjust **Marker "◀ ▶"** to fine tune the harmonic marker.

To fine tune the harmonic marker with greater accuracy, measure a single spectrum with **Frequency Axis "Lin."** in the **"Frequency Mode"** and then:



① Move the cursor to the fundamental frequency using **Cursor "◀ ▶"**.

② Press **Marker "Harmonic"**.

③ Adjust **Marker "◀ ▶"** to fine tune the harmonic marker.

④ Move the cursor to a clearly defined high order harmonic (on the right of the screen) using **Cursor "▶"**.

⑤ Press **Special Function "Zoom"**.

⑥ Adjust **Marker "◀ ▶"** to further fine tune the harmonic marker.

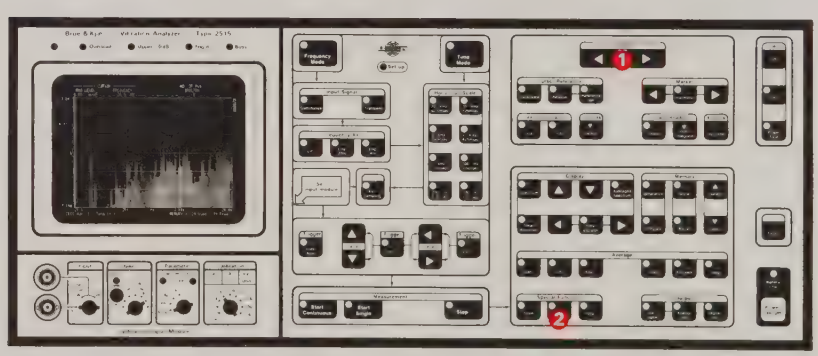
⑦ Press **Special Function "Zoom"** to return to the baseband (unzoomed) spectrum.

⑧ Move the cursor to the fundamental frequency using **Cursor "◀"** and read the updated fundamental frequency.

4.4. Cepstrum Analysis

Cepstrum analysis is used to identify families of harmonics and of sidebands. The cepstrum reduces each harmonic or sideband family to a single component and a small number of rhamonics. This reduction of the displayed data allows individual harmonic families to be more easily identified and studied.

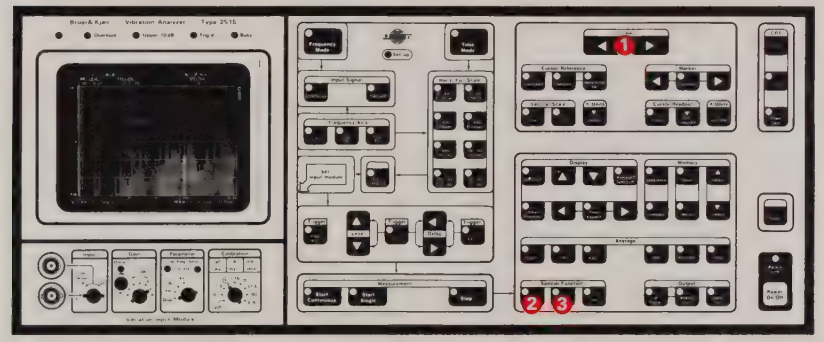
Cepstrum analysis can be performed on both baseband (unzoomed) and zoomed spectra. To perform a cepstrum on a baseband spectrum, measure a single or averaged spectrum with **Frequency Axis "Lin."** and then:



① Move the cursor to select the frequency span used for the cepstrum using **Cursor "◀ ▶"**. Frequencies to the left of the cursor are not used when calculating a cepstrum from a baseband spectrum. (The cursor is used as a high pass filter).

② Press **Special Function "Cepstrum"**.

To perform a cepstrum on a zoomed spectrum, measure a single spectrum with **Frequency Axis "Lin."** and then:



① Move the cursor to select the centre frequency of the zoom using **Cursor "◀ ▶"** Frequencies outside the zoom are not used when calculating a cepstrum from a zoomed spectrum. (The zoom is used as a bandpass filter).

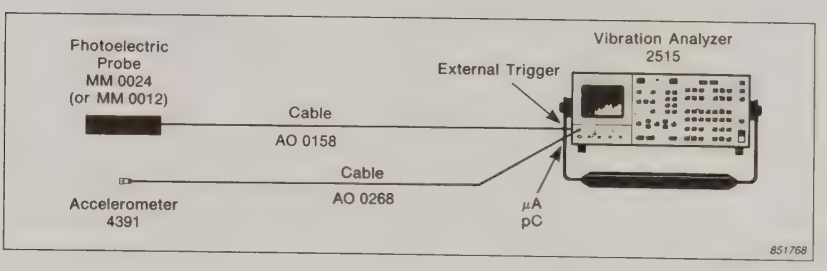
② Press **Special Function "Zoom"**.

③ Press **Special Function "Cepstrum"**.

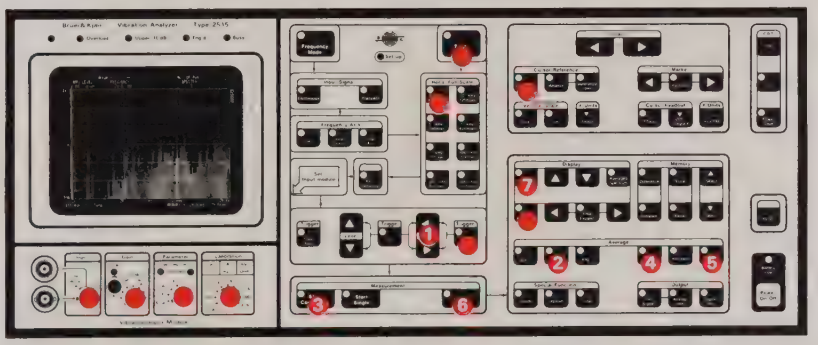
4.5. Time Averaging

Time averaging is most often used with an external trigger so that the average may be synchronized with any shaft or rotor of the machine under investigation. The main uses of synchronous time averaging are:

1. To remove noise from the vibration signal.
2. To remove vibration signals non-synchronous with the trigger signal, separating vibrations of shafts in gearboxes, eliminating electrically induced vibrations, separating vibrations of adjacent non-synchronous machines, etc.
3. To study the averaged phase of the vibration signal for balancing, etc.
4. To study reciprocating engine cycles.



To measure a time averaged spectrum with an external trigger and **Horiz. Full-Scale "20 kHz"**, connect the photoelectric probe MM 0012 or MM 0024 and mount the probe so that a piece of reflective tape on the rotor surface will trigger the probe. Mount the accelerometer at the required measurement point and then:



○ Set the controls and pushbuttons marked with a blank circle.

① Adjust the **Trigger Delay "◀ ▶"** as required. (This is usually **"0"**).

② Press **Average "Lin."**.

③ Press **Measurement "Start Continuous"**.

④ Press **Average "Start"**.

⑤ Press **Average "Stop"** when the time function display no longer changes.

⑥ Press **Measurement "Stop"**.

⑦ Press **Display "Spectrum"**.

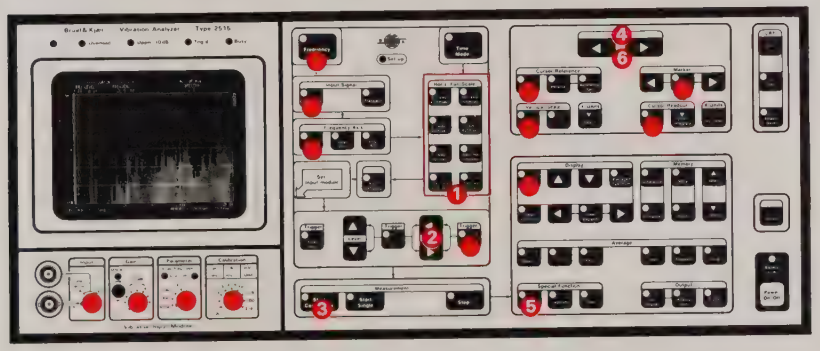
Both cepstrum analysis and the harmonic marker can be used with the time averaged spectrum.

4.6. Phase Measurement

The main applications of phase measurement are balancing, detecting cracks in shafts and investigating the mode of vibration. The phase measurement is only meaningful with a known reference point and is usually made relative to an external trigger synchronous with the rotational speed. The recommended method of measurement is to use either a zoomed spectrum analysis or time averaging to remove the noise from the vibration signal. When time averaging, a frequency multiplier should be used to track speed variations greater than $\pm$ 1/8 of one line width. See section 4.7.

Marker "Harmonic" is selected automatically to measure more accurately the phase and amplitude at the cursor position. The cursor must be positioned on a prominent peak.

To measure the phase at the rotational speed using the zoom, connect the photoelectric probe MM 0012 or MM 0024 and mount the probe so that a piece of reflective tape on the rotor surface will trigger the probe. Mount the accelerometer at the required measurement point and then:



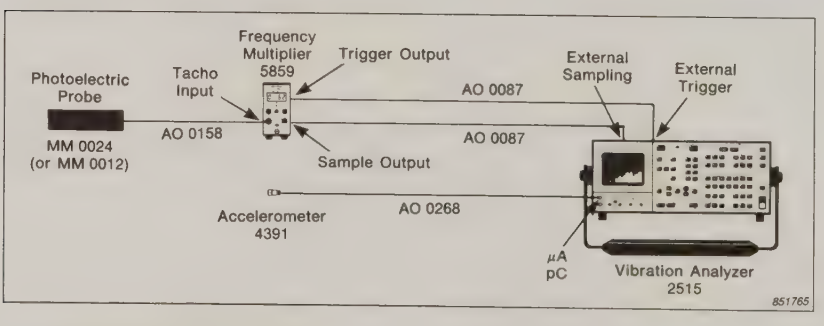
- ○ Set the controls and pushbuttons marked with a blank circle.
- ① Select the **Horiz. Full-Scale** so that the rotational frequency will be within the first 8 lines of the spectrum display.
- ② Adjust the **Trigger Delay "◀ ▶"** as required. (This is usually **"0"**).
- ③ Press **Measurement "Start Continuous".**
- ④ Move the cursor to the rotational speed using **Cursor "◀ ▶"**.
- ⑤ Press **Special Function "Zoom"**.
- ⑥ Move the cursor to the rotational speed using **Cursor "◀ ▶"**. The phase at the cursor position is shown at the top of the display screen.

If the phase variation is unacceptable, try increasing the **Horiz. Full-Scale** or try time averaging.

4.7. Tracking

Tracking order analysis is used on machines with variable rotational speed to keep the speed related components on fixed lines in the spectrum. Tracking is achieved using a frequency multiplier and a tachometer probe to generate an external sampling frequency related to the speed of the machine. The spectrum is defined by line number rather than frequency. The main applications of tracking are:

1. To study the phase when balancing to compensate for speed drift.
2. To study the evolution of components and harmonics that are a function of speed.
3. To determine critical speeds during run up and coast down.

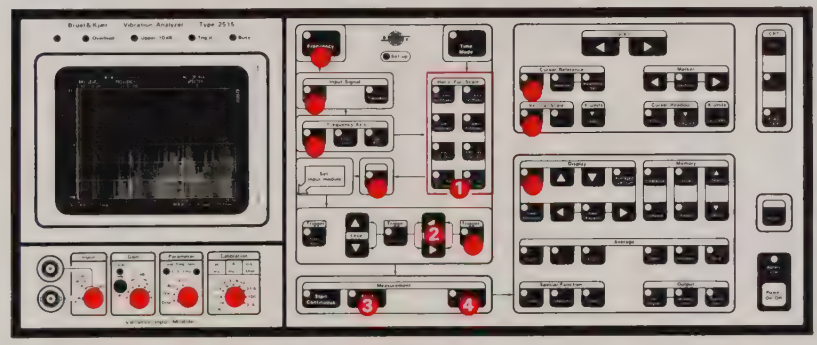


The multiplication factor is:

$$N = \frac{2048}{L_{Trig}}$$

where L_{Trig} is the line number of the trigger frequency in the baseband spectrum. A multiplication factor of 256 is recommended as this gives a line number of 8 which is the highest line number for accurate phase measurement.

To measure a spectrum with tracking and **Frequency Axis "Lin."**, first connect the photoelectric probe MM 0012 or MM 0024 and mount the probe so that a piece of reflective tape on the rotor surface will trigger the probe. Mount the accelerometer at the required measurement point and then:



○ Set the controls and pushbuttons marked with a blank circle. Note that **"Ext. Sampling"** is now selected.

① Select the **Horiz. Full-Scale** frequency immediately below the frequency:

$$\frac{256 \times \text{maximum trigger frequency}}{L_{Trig}}$$

② Adjust the **Trigger Delay "◀ ▶"** as required. (This is usually **"0"**).

③ Press **Measurement "Start Single"**.

④ Wait until **Measurement "Stop"** is lit.

The highest valid screen line will be the lower of:

$$\frac{2097 \times \textbf{Horiz. Full-Scale} \text{ frequency}}{\text{maximum trigger frequency} \times N}$$

or

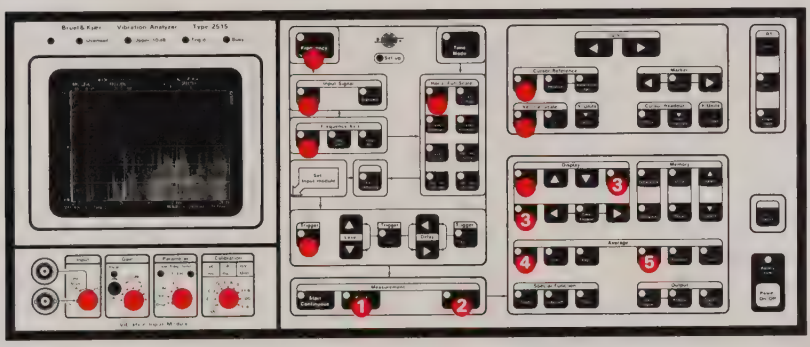
$$1024 - \frac{6292 \times \textbf{Horiz. Full-Scale} \text{ frequency}}{\text{minimum trigger frequency} \times N}$$

4.8. Scan Averaging

Scan averaging is a method of analysing changes across the time record. The time signal recorded by the 2515 is analysed step by step. The recorded time signal is 5 times longer than the signal required for an analysis. With **Frequency Axis "Lin."** selected, 17 analyses are performed, equally spaced in time. The display is seen to change in time as the analysis steps through the time record. The main applications are:

1. To study non-stationary signals.
2. To study reciprocating engine cycles.
3. To study short duration run ups and coast downs as found with electrical machines and gas turbines.

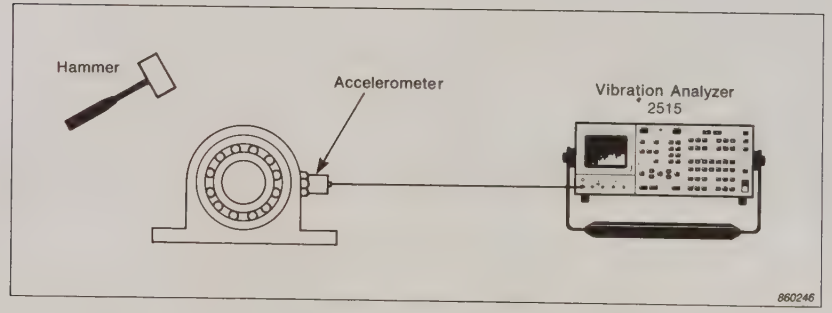
Choose the **Horiz. Full-Scale** according to the length of time record required. For example, to measure a scan average with **Horiz. Full-Scale "20 kHz"** and **Frequency Axis "Lin."**:



- ○ Set the controls and pushbuttons marked with a blank circle.
- ① Press **Measurement "Start Single"**.
- ② Wait until **Measurement "Stop"** is lit.
- ③ Select **Display "Spectrum"**, **"Averaged Spectrum"** or **"Time Function"** as required.
- ④ Press **Average "Scan"**.
- ⑤ Press **Average "Start"**. **Average "Stop"** and **"Proceed"** can be used to stop and start the display during the analysis.

4.9. Resonance Check

This is a quick method for finding structural resonances which may cause high vibration levels at certain frequencies. Typical sources are coupling resonance, bearing resonance and gear resonance.



As a guide, choose the **Horiz. Full-Scale** from the following table:

Machine Part	Mounting	Gear	Bearing	Coupling
Horiz. Full-Scale	"200 Hz"	"20 kHz"	"20 kHz"	"1 kHz"

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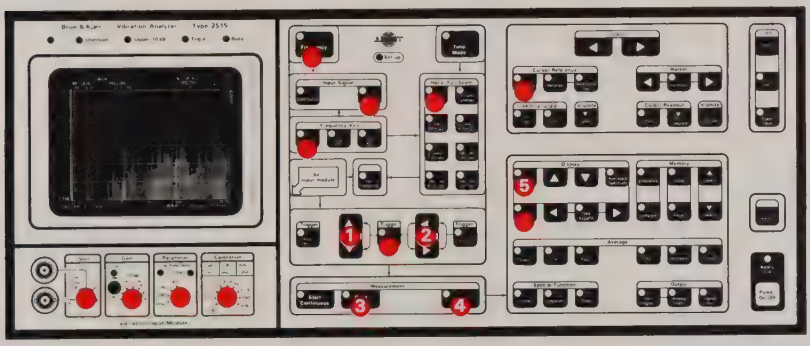
To perform a resonance check with **Horiz. Full-Scale "20 kHz"** and **Frequency Axis "Lin."**:



○ Set the controls and pushbuttons marked with a blank circle.

① Adjust the **Trigger Level "▲ ▼"** by trial and error so that an impact will trigger the 2515 (**"Trig'd"** will light).

② Adjust **Trigger Delay "◀ ▶"** to capture the beginning of the impact. Typically, set the trigger delay to **"0"** and then press **Trigger Delay "◀"** once.

③ Press **Measurement "Start Single"**.

④ Impact the structure and wait until **Measurement "Stop"** is lit. Check that the signal is from a single impact.

⑤ Press **Display "Spectrum"**.

5. Balancing

Unbalance is a common source of vibration in rotating machinery. Balancing will reduce excessive loads in support bearings and associated structures with a corresponding reduction of external noise and vibration. Balancing is achieved by adjusting the mass distribution of the rotor so that the resulting geometric and inertia axes more closely coincide with one another. Amplitude and phase are measured in one or two planes both with and without trial masses. Correction masses and their positions are calculated from these results.

As a general rule, two-plane balancing is used if the rotor diameter is less than 10 × the rotor thickness. Two accelerometers should be used for two-plane balancing, one at each measurement plane. Ideally, separate cables and a switch box should be used so that the accelerometers are not disturbed during the measurement. The Balancing Program WW 9021 and an HP 41 C calculator may be used to calculate the correction masses and positions.

The balancing procedure is as follows (with the two-plane procedures in brackets). The amplitude and phase are measured in both planes when two-plane balancing.

1. Mount the tachoprobe and accelerometer(s) and measure the initial amplitude and phase.
2. Mount a known trial mass (at plane 1) and mark its position.
3. Record the amplitude and phase.
4. Remove the trial mass.

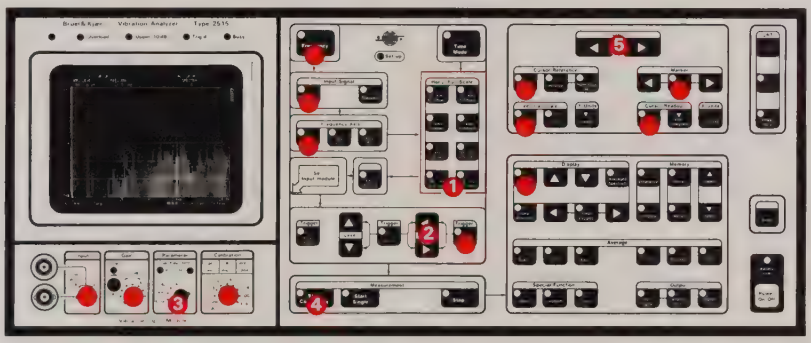
(5). Mount a known trial mass at plane 2 and mark its position.

(6). Record the amplitude and phase.

(7). Remove the trial mass.

8. Calculate the correction mass and angle.
9. Make the mass correction to the rotor and check the amplitude and phase.

To measure the amplitude and phase, first connect the photoelectric probe MM 0012 or MM 0024 and mount the probe so that a piece of reflective tape on the rotor surface will trigger the probe. Mount the accelerometer at the plane to be measured and then:



○ Set the controls and pushbuttons marked with a blank circle.

① Select the **Horiz. Full-Scale** so that the rotational frequency will be within the first 8 lines of the spectrum display (i.e. choose **"2 kHz"** for a rotor speed between 50 and 60 Hz).

② Set the **Trigger Delay "◀ ▶"** to **"0"**.

③ Set **Parameter "Vel."**.

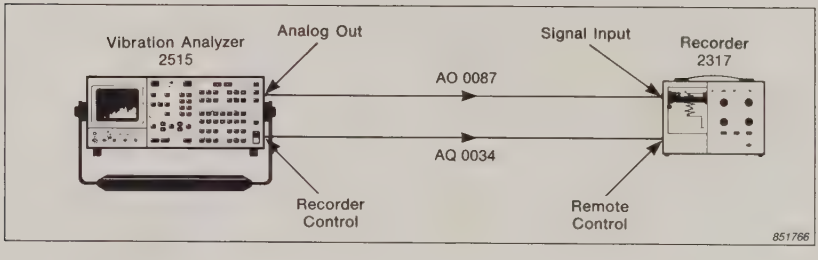
④ Press **Measurement "Start Continuous"**.

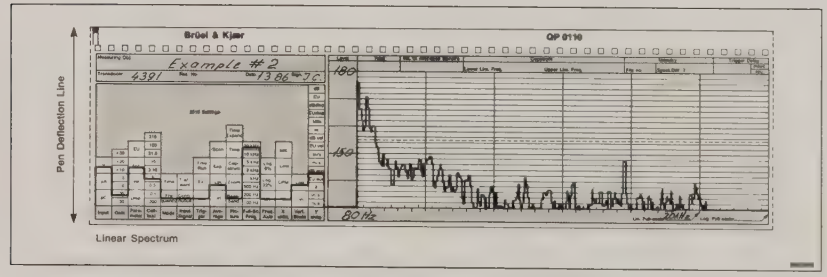
⑤ Move the cursor to the rotational speed component using **Cursor "◀ ▶"** and measure the amplitude and phase.

If the phase value changes by more than 4 degrees, try increasing the **Horiz. Full-Scale** or use a frequency multiplier. See section 4.7. Note that **Special Function "Zoom"** can be used to separate components close to the rotational frequency but will slow-down the measurement.

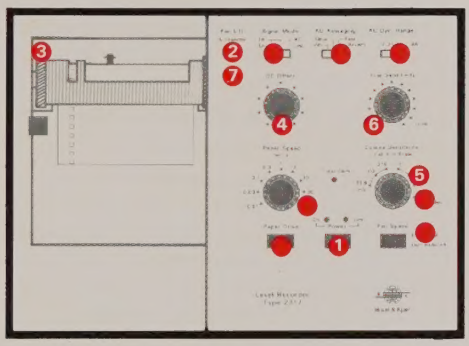
6. Hard Copying

The Level Recorder Type 2317 can be used in the field to produce an immediate hard copy of the 2515 screen display and settings. The current display or any display stored in the memory may be copied using the 2317.





To calibrate the 2317 for use with the 2515:



○ Load the Recording Paper QP 0110 and set the 2317 as follows:
Paper Speed "Ext."
Paper Drive "On" (pushbutton in)
Pen Speed "Normal"
Signal Mode "DC Lin +"
AC Averaging "Fast"
AC Dyn. Range "50 dB"
Coarse Sensitivity
"Input Grounded"

① Switch on the 2317.

② Select **Pen Lift & Standby "Off"** (pushbutton out).

③ Adjust the paper so that the pen is on the **"Pen Deflection"** line.

④ Adjust the **DC Offset** knob to move the pen to the bottom (right hand edge) of the **"Pen Deflection"** line.

⑤ Select **Coarse Sensitivity "10 V"**.

⑥ Select **Fine Sensitivity "0 dB Cal."**.

⑦ Select **Pen Lift & Standby "On"** (push-button in). The 2317 is now calibrated for use with the 2515.

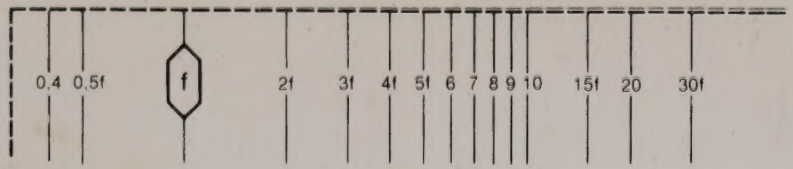
6.2. Use of 2317

To copy from the 2515 display or memories:

1. Display the required function on the 2515 display screen. Only the upper 50 dB of a spectrum will be recorded with **Vertical Scale "Log."** selected.
2. Select **Pen Lift & Standby "Off"** (pushbutton out) on the 2317.
3. Press **Output "Analog Out"** on the 2515. The displayed function will be recorded on the paper. **Output "Analog Out"** will cancel automatically at the end of the record and the pen will move to the beginning of the next record.
4. The vertical scale and any supplementary information from the display screen must be written on the recording paper by hand.

The overlay (opposite) may be used with the Recording Paper QP 0110.

2317 Log. Scale Overlay



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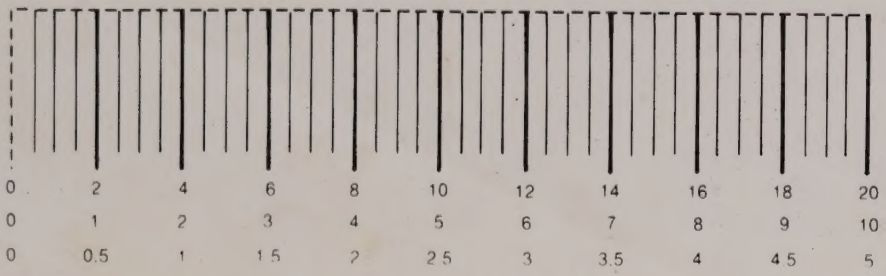
2317 Lin. Scale Overlay



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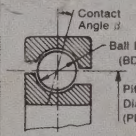
Nature of Fault	Frequency of Dominant Vibration (Hz=rpm/60)	Direction	Remarks
Rotating Members out of Balance	1 × rpm	Radial	A common cause of excess vibration in machinery
Misalignment & Bent Shaft	Usually 1 × rpm Often 2 × rpm Sometimes 3&4 × rpm	Radial & Axial	A common fault
Damaged Rolling Element Bearings (Ball, Roller, etc.)	Impact rates for the individual bearing component* Also vibrations at high frequencies (2 to 60 kHz) often related to radial resonances in bearings	Radial & Axial	Uneven vibration levels, often with shocks. * Impact Rates:  **Impact Rates f (Hz)** For Outer Race Defect $f(Hz) = \frac{n}{2} f_r \left(1 - \frac{BD}{PD} \cos \beta\right)$ For Inner Race Defect $f(Hz) = \frac{n}{2} f_r \left(1 + \frac{BD}{PD} \cos \beta\right)$ For Ball Defect $f(Hz) = \frac{PD}{BD} f_r \left[1 - \left(\frac{BD}{PD} \cos \beta\right)^2\right]$ n = number of balls or rollers f_r = relative rev./s between inner & outer races
Journal Bearings Loose in Housing	Sub-harmonics of shaft rpm, exactly 1/2 or 1/3 × rpm	Primarily Radial	Looseness may only develop at operating speed and temperature (e.g. turbomachines).
Oil Film Whirl or Whip in Journal Bearings	Slightly less than half shaft speed (42% to 48%)	Primarily Radial	Applicable to high-speed (e.g. turbo) machines.
Hysteresis Whirl	Shaft critical speed	Primarily Radial	Vibrations excited when passing through critical shaft speed are maintained at higher shaft speeds. Can sometimes be cured by checking tightness of rotor components.
Damaged or Worn gears	Tooth meshing frequencies (shaft rpm × number of teeth) and harmonics	Radial & Axial	Sidebands around tooth meshing frequencies indicate modulation (e.g. eccentricity) at frequency corresponding to sideband spacings. Normally only detectable with very narrow-band analysis and cepstrum
Mechanical Looseness	2 × rpm		Also sub- and interharmonics, as for loose Journal bearings
Faulty Belt Drive	1, 2, 3 & 4 × rpm of belt	Radial	The precise problem can usually be identified visually with the help of a stroboscope
Unbalanced Reciprocating Forces and Couples	1 × rpm and/or multiples for higher order unbalance	Primarily Radial	
Increased Turbulence	Blade & Vane passing frequencies and harmonics	Radial & Axial	Increasing levels indicate increasing turbulence
Electrically Induced Vibrations	1 × rpm or 1 or 2 times synchronous frequency	Radial & Axial	Should disappear when turning off the power

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